“ I hereby declare that I have read through this report entitle “Design, Construction and Analysis of Biped Robot for Walking Motion” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature	:	…………………………..
Supervisor’s Name	:	…………………………..
Date	:	…………………………..

DESIGN, CONSTRUCTION AND ANALYSIS

OF BIPED ROBOT

FOR WALKING MOTION

JIM KAI YIAT

A report submitted in partial fulfillment of the requirements for the degree

of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013/2014

I declare that this report entitle “Design, Construction and Analysis of Biped Robot for Walking Motion” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	…………………………..
Name	:	…………………………..
Date	:	…………………………..

ACKNOWLEDGEMENT

Many people have helped and guided me through the whole process of preparing this report. I am much indebted and thankful. In particular, I would like to thank my supervisor Dr Fariz Bin Ali @ Ibrahim, for his patience, teachings, encouragement and motivation in making this report possible. I would also like to thank Cik Nur Maisarah Bt Mohd Sobran and Encik Tarmizi Bin Ahmad Izzuddin for sharing their knowledge in solving my problems. Without any of their helps, this project would not have been the same as presented here.

Besides, all of my fellow friends that have accompanied and advised me are much appreciated. Their point of view and critics are the fundamental to the improvement of my project. Finally, I feel grateful to all the people who have helped even if it is just a small favor. I will also like to express my humble apology to everyone for the trouble I may have caused.

ABSTRACT

This report emphasize on the design, construction and analysis of biped robot for walking motion. This study is important since humanoid robots have been developed for a long period of time which benefits human in terms of aiding orthosis and prosthesis, understanding human body, creating human assistance and improving entertainment field. Therefore, development of biped robot would be the first step in completing this approach. Besides, the objectives of this project are to design and develop a biped robot with humanlike motion capability controlled by Arduino microcontroller and to analyse the biped robot walking motion by static motion sequence and joint angle. The literature review focuses on the design and basic construction of the biped robot including the walking analysis. Similarly, the execution of the project is separated into biped robot construction in FYP1 and analysis in FYP2. Moreover, the methodology of this project is to design the robot structure using SolidWorks, design the electrical and electronic configuration using Proteus ISIS, stability study and controller application. Parameters such as servo motor angle of rotation, center of mass and static walking motion are obtained and analysed in terms of the capability to achieve stable forward walking motion. Error analysis and trajectory analysis will be carried out to see the performance of the biped robot walking motion as compared to the actual human walking motion. Lastly, the outcome of this project is a functional biped robot with capability of walking forward in a smooth surface using static walking motion.

ABSTRAK

Laporan ini memberi penekanan kepada reka bentuk, pembinaan dan analisis robot “biped” untuk pergerakan berjalan. Kajian ini adalah penting kerana robot “humanoid” telah dibangunkan untuk tempoh masa yang panjang serta memberi manfaat kepada manusia dari segi pembangunan “orthosis” dan “prosthesis” , pemahaman tubuh manusia , pembentukan sistem bantuan manusia dan peningkatan bidang hiburan. Oleh itu, pembangunan robot “biped” akan menjadi langkah pertama dalam menyelesaikan pendekatan ini. Selain itu, objektif projek ini adalah untuk mereka bentuk dan membangunkan robot “biped” dengan keupayaan untuk bergerak sama dengan pergerakan manusia dengan kawalan mikropengawal Arduino dan untuk menganalisis robot “biped” berjalan dalam turutan pergerakan statik beserta sudut sendi . Kajian sastera memberi tumpuan kepada reka bentuk dan asas pembinaan robot “biped” dan juga analisis pergerakan berjalan. Lebih-lebih lagi , pelaksanaan projek ini dibahagikan kepada pembinaan robot “biped” dalam PSM1 dan analisis dalam PSM2 . Selain itu, metodologi projek ini meliputi reka bentuk struktur robot menggunakan program SolidWorks , reka bentuk konfigurasi elektrik dan elektronik menggunakan Proteus ISIS , kajian kestabilan dan penggunaan “pengawal” . Ciri-ciri seperti sudut putaran motor servo, pusat jisim dan gerakan berjalan statik akan diperolehi dan dianalisis dari segi keupayaan untuk mencapai pergerakan ke hadapan dalam keadaan berjalan stabil. Analisis ralat dan analisis generasi trajektori akan dilakukan untuk melihat keupayaan robot “biped” dalam pergerakan berjalan berbanding pergerakan berjalan manusia. Akhir sekali , hasil daripada projek ini adalah sebuah robot berkaki dua yang mampu untuk berjalan ke hadapan di permukaan yang licin dengan pergerakan statik.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

M	-	Mass
L	-	Length
θ	-	Angle
X_{COM}	-	Length of COM from reference point
θ_0	-	Initial angle
θ_v	-	Via point angle
θ_g	-	Final angle/ goal angle
H_R	-	Hip of right leg
K_R	-	Knee of right leg
A_R	-	Ankle of right leg
H_L	-	Hip of left leg
K_L	-	Knee of left leg
A_L	-	Ankle of left leg
T	-	θ

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Motivation

Development of humanoid robot has been around for a long time. It has been used as an experiment tool in many scientific environments.

Initially, humanoid robots are developed for orthosis and prosthesis research purposes. This can be seen in the development of human orthotics and prosthetics equipments such as motorized leg and arm for neural or muscle impaired patient, biological realistic prosthetics, ankle to foot orthotics tool and much more. This is important because the future demand for orthotic and prosthetic services is expected to increase tremendously according to a study carried out by Caroline Nielsen. The exact statistics can be seen in Appendix A. Besides, based on an article published in 2009 [1], there is a total of 125000 patients in needs for prosthetic and orthotics services which is deemed to increase throughout the years.

Secondly, humanoid robots are also built so that the human body structure and behavior (biomechanics) can be learned. This leads to simulation of human body for further understanding and cognition study where human ability to analyse sensory information is being discussed for obtaining intuitive and motor techniques.

Moreover, human assistance is also made possible with the improving technology on humanoid robots. In this modern era, humanoid robots are being modified into a robot that can perform human tasks such as assisting the sick and elders, doing dangerous task such as fixing electrical cable, space exploration and much more. Theoretically, since humanoid is built in a form of a human body, it can basically do any task human are capable of, with a suitable algorithm.

Finally, the gaining popularity of humanoid robot in the entertainment field has brought to its development for the same purpose. For example, Ursula is a female robot capable of singing, dancing and interacting with audience at the Universal studios. Ursula has been developed by the Florida Robotics [2]. These robots have realistic expression and gestures that are comparable to human but they do not have cognition or physical anatomy.

These factors have contributed to the interest in understanding humanoid robot and biped robot development would be a beginning of it.

1.2 Problem Statement

Vast theoretical knowledge in robotics field is needed in designing and constructing a biped robot. These robots are controlled mainly by servo motors, microprocessors and control system. To achieve stable static motion, the robots design must achieve stability during stationary and moving motion, not forgetting the kinematics and dynamics of the robot which plays an important part in robot structure development. In current studies, all of these are possible; hence, the focus of this project is more to the implementation of the microprocessor which is the Arduino, the basic knowledge and skills in developing a biped robot (e.g. servo motor control, kinematics and stability derivation) and most importantly the analysis on the walking motion. The analysis includes the different walking combination implementation to find the best length of stride, height of stride and speed of stride for the walking motion. Besides, there is also error analysis to measure the accuracy of the Dynamixel AX-12A servo motor. Lastly, the trajectory generation analysis is conducted to compare the assumed walking motion of a human with the walking experimental walking motion of the biped robot. This analysis is done to obtain a better understanding on imitation of a human walking motion in a biped robot.

1.3 Objectives

1. To design and develop a biped robot with humanlike motion capability controlled by Arduino microcontroller.
2. To analyse the biped robot walking motion by static motion sequence and joint angle.

1.4 Scopes

1. The robot have 12 D.O.F with 3 axis of rotation (roll, pitch, yaw) and Dynamixel AX-12 servo motor capable of having large angle of rotation that compromises human movement.
2. Arduino is used as the main microcontroller and built-in PID is used as the controller.
3. Biped robot should only move/walk in forward motion by implementing static movement.
4. The frame and parts of the robot will be consisting of plastic/polymer that is lightweight, cheap and robust.
5. Only left leg of the biped robot is developed and the right leg will be developed by another course mate. This is due to the budget limitation and complexity.

CHAPTER 2

LITERATURE REVIEW

2.1 Design and Basic Construction

By using the measurements, dimension and degrees of freedom (D.O.F) of the robot “Denise” which was developed by Delft University [3], a similar robot was built for research use [4]. The robot has a total of 5 degrees of freedom with 1 degree of freedom at the hip, 2 degrees of freedom at the knee and 2 degrees of freedom at the ankle. Besides, it is made of mainly aluminum material. The main actuator used [4], is the pneumatic muscle or the McKibben muscle which expand its size with the increase of pressure causing the muscle to shorten and produces a force to the pneumatic piston attached to the hip. This in turn collaborates with the interlock system in the knee to remain fixed when the leg swings forward and bent during forward movement. Lastly, the author proposes the use of 16F84A microcontroller which is programmed using C language to control the robot. The microcontroller works simply by detecting the signal given by the sensors mounted on the sole and take appropriate action based on the given programming. The finished prototype is shown in Figure 2.1.

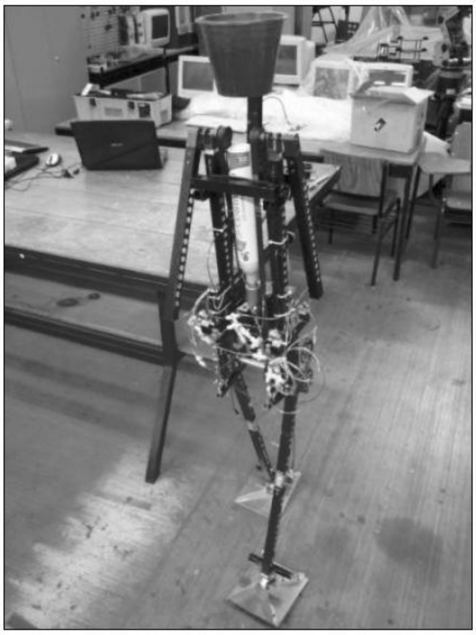

Figure 2.1: "Denise" prototypes [4]

On the contrary, Kanagawa Biped Robot-1 Refined or KBR-1R [5] has a total of 12 degrees of freedom with 6 degrees of freedom at the hip, 2 degrees of freedom at the knee and 4 degrees of freedom at the ankle. The author emphasize that the movable angle of KBR-1R is about the same as a human so that it could simulate the movements similar to a human. Besides, the material primarily used in this robot is aluminum. The D.O.F configuration is shown in Figure 2.2.

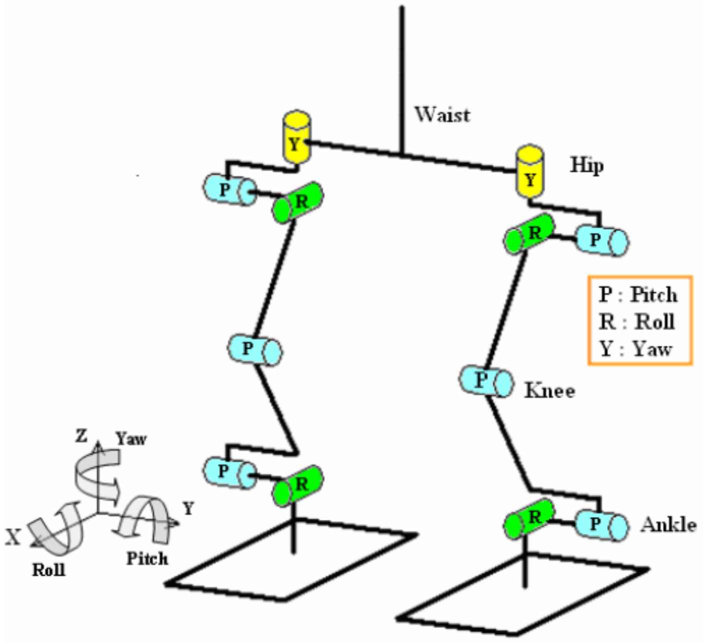

Figure 2.2: D.O.F configuration of KBR-1R [5]